First Annual Progress Report
NASW-96007
Energy coupling between the ionosphere and inner magnetosphere
related to substorm onset

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30 April 1997

Covering period from June 1996 to June 1997

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*Summary:* From that list of 75 potentially interesting events with CRRES data, we have selected 13 events for detailed analysis in the initial study. We are also assembling the correlative ground-based data. Dusk-dawn excursions of the electric field continue to be present as an apparent precursor and appear to be a necessary condition for onset. Significant field-aligned Poynting flux is observed returning from the ionosphere after the initial flow downward, emphasizing the importance of magnetosphere-ionosphere coupling. The energy in the reflected Poynting flux associated with onset local to CRRES appears to decrease with distance from the local time of onset. If it occurs, the "explosive growth phase" feature noted in the 540 event shortly after start of dipolarization appears to occur later after start of dipolarization, the further away in local time from the local time of onset, and is associated with a particle injection. In isolated events, dipolarization appears (apart from the explosive growth phase signature) to occur at constant rate of increase in Bz. The "explosive growth phase" feature we refer to is the magnetic field perturbation associated with a large Alfvén pulse traveling toward, and then reflected from, the ionosphere. The delay between substorm onset and local onset at CRRES appears to increase with local time distance from the pre-onset Harang discontinuity. This indicates that onset occurs near the pre-onset Harang discontinuity. A paper was presentd at Fall AGU, and we have been invited to give a paper at the NATO Advanced Study Institute on boundary layers and related phenomena which will be held at Longyearbyen, Norway, in the Svalbard archipelago in June of this year. NCM will present the paper.

Factual data and continuing analysis

A list of the 75+ potentially interesting events was constructed, noting if CRRES and a LANL satellite were positioned within an hour of LT. From the list, 53 two-hour intervals were selected in which magnetic perturbations due to FACs were evident, and the angle between electric and magnetic fields exceeded 20 degrees (so three components of electric field could be computed from E.B=0 condition, and three components of Poynting flux could be computed). E, B, and delta-B were computed and plotted in both MGSE and VDH coordinate systems. As well, E and B were put into field-aligned coordinates and the Poynting vector (30 sec resolution) was computed. LEPA data was plotted also. 13 events were selected for a first comprehensive examination forming the "short list". Ground tracks were produced. Preliminary ground magnetometer data has been obtained for most. After first inspection, we have requested higher resolution data and data from additional stations.

Results from short list: The following represent work-in-progress "conclusions" based on our present state of analysis (PAPER 1 refers to Maynard et al, JGR, 7705, 1996).

a. The delay between start of dipolarization and electron injection observed at CRRES found in PAPER 1 persists in each event studied. A delay of at least 4 minutes is evident.

b. Also in PAPER 1 we hypothesized that a brief reversal of the convection electric field from dawn-dusk (westward) to dusk-dawn (eastward) preceded local onset. Many of the new events (from the sub-list) also show the electric field reversal prior to onset; however, the farther away from the onset region, the less clear the association of a particular electric field variation becomes.

c. We had only 3 events from the PAPER 1 where the Poynting vector could be computed. These events showed that the dusk-dawn excursion of the electric field was accompanied by Poynting flux toward the ionosphere. If its reflection (subsequent upward Poynting flux) were in phase (based on an Alfvén transit time to the ionosphere and back), then onset resulted. If the reflected energy arrived out of phase with respect to the initial downward energy flux, only a pseudobreakup occurred. Out-of-phase arrival of upward energy flux could also locally turn off an energy release already in progress. Our new list was selected to examine this M-I coupling associated with onset at CRRES. The events in the short list appear consistent with the M-I coupling seen in the first three events.

d. Three trends may be present in the data from the short list: (i) The energy in the reflected Poynting flux associated with onset local to CRRES appears to decrease with distance from the local time of onset. (It may also be that the energy in the initial downward pulse decreases with local-time distance from substorm onset.) (ii) If it occurs, the "explosive growth phase" feature noted in the 540 event shortly after start of dipolarization appears to occur later after start of dipolarization the further in local time from the local time of onset and is associated with a particle injection. In isolated events, dipolarization appears (apart from the explosive growth phase signature) to occur at constant rate of increase in Bz. The "explosive growth phase" feature we refer to is the magnetic field perturbation resulting from a large Alfvén pulse traveling toward then reflected from the ionosphere. (iii) The delay between substorm onset and local onset at CRRES appears to increase with local time distance from the pre-onset Harang discontinuity. This indicates that onset occurs near the pre-onset Harang discontinuity.

Based on the above results, substorm onset occurs near or within the inner-edge region of the plasma sheet, as close as 5-6 Re in radial distance. The mechanism of onset appears consistent with ballooning. Theoretical expectations assuming ballooning places onset within 2 Re of the inner edge of the plasma sheet. Thus, onset occurs somewhere between 5--7 or 6--8 Re in radial distance, and in proximity to the mapping in local time of the pre-onset Harang discontinuity. When verified, these results place new constraints on the onset process for verification of onset theories or construction of a new theory.

Our analysis of the electrodynamics will continue in the upcoming year. Also, the onset mechanism that appears most consistent with the CRRES observations is ballooning. Measurements of ion pressure, pressure gradient direction are important parameters wrt ballooning. While LEPA results are readily accessible, ion data (e.g., from the MICS instrument) are not. Several requests for ion data for event 540 have gone unanswered. We shall renew our requests. We also intend to examine the wave power. If the wave power in the minutes leading up to current wedge formation increases dramatically near the ion gyrofrequency, then this would argue in favor of Lui's current disruption theory as the onset mechanism. The increase at low frequency favors a ballooning mechanism.

Papers and other collaborations:

Dr. Erickson of Boston University presented a paper at Fall AGU entitled "CRRES observational constraints for substorm onset", by Erickson, Burke, Heinemann, and Maynard - SM12B-04.

We have been invited to present a paper on the characteristics of substorms in the inner magnetosphere at the NATO Advanced Study Institute on boundary layers and related phenomena which will be held at Longyearbyen, Norway, in the Svalbard archipelago in June of this year. NCM will present the paper.

CRRES data plots were also sent to Dr. Reijo Rasinkangas in Finland for a substorm study which he and Dr. Victor Sergeev of Russia are currently pursuing.

Our present studies involve Drs. Reeves of Los Alamos, Samson of Canada and Yahnin of Russia.